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RESEARCH ARTICLE
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Impact of Phosphorus Fertilization and *Rhizobium* Inoculation on the Growth, Production, and Forage Quality of Peanuts (*Arachis Hypogaea* L.)

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ABSTRACT

This study used a factorial Complete Randomized Design (RAL) consisting of factor A (phosphorus level) and factor B (addition of *Rhizobium* inoculation). The research treatment was as follows: Factor A=phosphorus level, P0: control phosphorus level or 0kg, P1: phosphorus level 0.25g SP36/polybag, P2: phosphorus level 1g SP36/polybag. While factor B=addition of *Rhizobium* inoculation, I0: without addition of *Rhizobium*, I1: addition of *Rhizobium* 2.5 gr/polybag. The parameters observed were plant height growth, fresh matter and dry production, number and weight of pods, number and weight of pods and seeds, quality of crude protein content and crude fiber content. The results of this study showed that the application of phosphorus and *Rhizobium* fertilizers had no real effect (P>0.05) on plant height, and no real effect on dry matter production, number, and weight of pods, and not the nutritional quality of crude fiber and crude protein, but a real effect (P<0.05) on the root nodules, fresh matter and the number and weight of seeds. There is an interaction between the application of phosphorus fertilizer and the addition of *Rhizobium* bacteria on the parameters of the root nodules, pod weight, number of seeds, crude protein content and crude fiber. The best treatment combination among several treatments is the combination of P2I1 with a fertilization dose of 1g/polybag with the addition of 2.5g *Rhizobium* inoculation.

Keywords: Peanuts; Phosphorus; *Rhizobium*; Root nodules.

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INTRODUCTION

Peanuts (*Arachis hypogaea L.*) originating from Brazil (South America) which has now spread to various tropical and sub-tropical climates, one of which is in Indonesia. Peanuts are used as direct consumption foodstuffs, or a mixture of foods such as bread, kitchen spices, industrial raw materials, and animal feed. Therefore, the development of the food industry and animal feed made from peanut raw materials has caused an increase in demand for domestic peanuts (Yulifianti et al., 2018).

Much research has investigated the effect of water and N availability on peanut plant growth, physiological characteristics, and yield formation (Basal and Szabó, 2020; Xia et al., 2021), but it is unclear how the interaction between water and N management affects peanut root growth and morphology. The relationships between root traits and pod yield (Ding et al., 2022).

The follow-up results of peanut plants in the form of straw and peanut shells. Peanut straw is the rest of peanut harvesting consisting of stems and leaves. Peanut straw is very preferred by ruminants and is classified as having a fairly high nutritional value. While the nutritional content of dried peanut straw is 24.76% dry matter, 10.53% crude protein, 34.28% crude fiber, 2.20% crude fat, 40.18% extract material without nitrogen (BETN), and 12.81% ash (Nurhasanah, 2020). Obstacles in increasing peanut crop production are infertile soil and unable to provide the nutrients needed. One of the efforts that can be made to increase peanut forage production is by fertilizing phosphorus combined with the use of inoculation *Rhizobium*. Combination treatment of phosphorus and inoculation *Rhizobium* It is possible to obtain quite a lot of forage yields both in terms of quality and quantity. Therefore, efforts are needed to improve soil fertility so that peanut productivity can be increased (Nurhasanah, 2020). According to Jorfi et al. (2022), combined with the

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correlation results, we considered that the appropriate phosphorus fertilizer application may have promoted the increase in nitrogen metabolism-related enzyme activity in the roots. It also promoted root growth and increased the absorption of rhizosphere soil nutrients, thereby increasing the aboveground biomass and final yield.

Addition of bacteria *Rhizobium* With phosphorus fertilizer is expected to have a positive impact on peanut production, such as improving the physical, chemical, and biological properties of the soil (Yulifianti et al., 2018). The addition of nutrients to the soil to increase crop production can be done by fertilizing phosphorus. While *Rhizobium* is a group of bacteria that are symbiotic with legume plants that are able to tether abundant N2, the results of their moorings can be used for plant growth. Bacteria *Rhizobium* It is classified as a gram-negative bacterium so that it can infect the roots directly when it is in the rhizosphere. After infecting the roots, *Rhizobium* will make colonies so that they form nodules that when split are pink. It is this colony that will later tether free N in the air effectively. N tethering is biologically highly dependent on organic matter in the soil. *Rhizobium* Requires energy derived from the overhaul of organic matter (Mwenda et al., 2023).

Gift *Rhizobium* at a dose of 2.5g/kg seeds in peanut plants, it can increase the dry weight of root nodules, the number of root nodules, plant height, number of leaves and leaf area (Taluta et al., 2017). The application of phosphorus fertilizer at a dose of 50kg/hectare has a very significant effect on the weight of dry seeds in plants, the number of nodules and the production of fresh peanut fresh matter (Rahmatullah, 2018). Based on this, research was conducted on the effect of phosphorus fertilization and *Rhizobium* on the production and quality of peanut forage (*Arachis Hypogaea L.*).

MATERIALS & METHODS

Material

The materials used are plant growing media (soil) 10kg/polybag, peanut seeds, water, *Rhizobium*, and phosphorus fertilizer.

Experimental Design and Treatment

The experiment was carried out in polybags with soil that had never been planted with peanuts. The study was arranged according to a complete randomized design of factorial patterns consisting of 2 factors and 3 repeats for each treatment. The number of treatment units 2×3×3=18 polybags. Using polybags measuring 29x25cm with a capacity of 10kg as many as 18 pieces. First Factor (A) Phosphorus fertilizer with a dose of 0kg/ha (P0=0g SP36*/polybag*), fertilizer dose 50kg / ha (P1=0.25g SP36/polybag) and fertilizer dose 200kg / ha (P2=1 gr SP36*/polybag*). Second Factor (B) *Rhizobium* inoculation at a dose of 0g/polybag (I0=0g *Rhizobium*/polybag) at a dose of 2.5g/polybag (I1=2.5g *Rhizobium*/polybag). Furthermore, randomize the position of the place, as for the results of the randomization can be seen in the picture below:

I0P12	I0P21	I1P23
I0P11	I1P22	I0P03
I1P03	I1P02	I1P01
I0P22	I1P12	I0P13
I1P21	I0P23	I0P02
I1P13	I1P11	I0P01

Fig. 1: Experiment design, lay out peanut plots.

Information:
I0P0=No inoculation and no fertilizer
I1P0=Inoculation (2.5g *Rhizobium*/polybag) + without fertilizer
I0P1=No inoculation + 0.25g SP36/polybag
I1P1=Inoculation (2.5g *Rhizobium* /polybag) + 0.25g SP36/polybag
I0P2=No inoculation + 1g SP36/polybag
I1P2=Inoculation (2.5g *Rhizobium* /polybag) + 1g SP36/polybag

Methods

Preparation

The soil media used in this study came from Pattondong Salu Village, Maiwa District, Enrekang Regency. The soil is analyzed to characterize soil fertility tests (pH, texture, organic matter). Soil analysis was carried out at the Laboratory of Soil Chemistry and Fertility, Faculty of Agriculture, Hasanuddin University.

Rhizobium Inoculation

Rhizobium inoculation uses pure culture inoculum with *Rhizobium sp*. species. Peanut seeds are partially separated to indicate between those inoculated with bacteria and those without.

Planting

Make a hole 2cm deep as many as 4 holes, and fill the hole of one peanut seed each both inoculated with *Rhizobium* bacteria and not in each polybag. After all the tools and materials are ready, planting is carried out. At the age of 2 weeks after planting, uproot two plants (uniformity) which initially contained four plants/polybags leaving two plants/polybags with uniform growth.

Fertilization

The fertilization process is carried out by applying different levels of phosphorus fertilizer each treatment by weighing fertilizers using analytical scales according to the dose used. Then sprinkle phosphorus fertilizers around the plants. After fertilizing, then plant maintenance is carried out.

Maintenance

Plant maintenance includes intensive watering, control of weeds, pests and diseases. Watering is carried out twice a day, namely morning and evening. Watering is carried out using lead. If it rains and the soil is already damp, there is no need for watering. Provision of support poles to plants that have grown high so that they are not easily collapsed or broken.

Parameter Measurement

Observations were made at the age of 100 days. In general, the harvest age of peanuts is 85-100 days.

Growth

Plant height is done by measuring plant height using a meter with a centimeter (cm) scale from the plant part above the ground to the tip of the plant shoot (canopy).

Forage Production

Root Nodule: Calculated the number of root nodules by the time the plant is 100 days old. By dismantling polybags in each experimental unit then the plant roots are cleaned of the remaining soil attached. Root nodules are calculated manually.

Production of Forage Fresh Ingredients: The fresh weight of forage is done by calculating the weight of the plant after cutting (above ground level). Plants will be taken on each sample (leaves and stems), then weighed to get the weight of the forage.

Number of Pods: Observation of the number of pods per plant is done by counting all pods in peanut plants. The number of pods per crop is determined by dividing the number of pods by the number of sample plants. The observation time is carried out after harvest. The weight of the dry pods per plant is weighed after a constant moisture content that is, after the pods are dried by drying for 3 days with sunlight.

Seed Weight: The dried pods are then peeled to separate the seeds from the pods. Next, the seeds are weighed in weight for each plot. The observation time is carried out after harvest.

Number of Seeds: Pods that have been counted from the sample plant, first the pods are peeled to separate the seeds from the pods. Next, seeds are counted from the entire pod of the sample plant. The number of seeds per pod is determined by dividing the whole seed by the number of pods per plant.

Dry Matter Production (DM): Production of dry matter (DM) is by calculating the weight of plants at the age of 100 days. The determination of dry matter levels is as follows:

Formula:

$$\% DM = \frac{(\text{Weight after oven} - \text{envelope weight}) \times 100\%}{\text{Fresh Weight Sample}}$$

Dry Matter Production=% DM × Fresh Matter Production

Forage Quality

Crude Protein Content: The protein content of a feed ingredient in general can be calculated by analyzing crude protein levels. This protein content analysis is an attempt to determine the protein content of feed raw materials. Protein content analysis is used to test protein levels, chemically determined nitrogen levels.

Crude Fiber Content: Crude fiber is the residue of foodstuffs or agricultural products after being treated with boiling acid or alkali, and consists of cellulose, with small amounts of lignin and pentose. Crude fiber is also a collection of all indigestible fibers, the components of this crude fiber consist of cellulose, pentoses, lignin, and other components. This component of crude fiber has no nutritional value, but this fiber is very important for the process of facilitating digestion in the body of livestock so that the digestive process is smooth (peristalsis).

Statistical Analysis

The test parameter data from the treatment with 2 factors were repeated 3 times and analyzed with a Complete Random Design (CRD) factorial pattern. At this stage, the test data is analyzed variously with SPSS 26.0. If the variance analysis shows influence between treatments, then proceed with the Duncan test.

RESULTS

Forage Growth of Peanut Plants Inoculation

The average forage growth of peanut plants inoculated with *Rhizobium* bacteria and different phosphorus fertilizers is presented in Table 1.

Based on the results of variety analysis in Table 2 shows that the application of phosphorus fertilizer with different levels from the application of *Rhizobium* does not have a noticeable effect ($P>0.05$) on plant height. Although the application of *Rhizobium bacteria* and phosphorus fertilizers has no noticeable effect on plant height. The combination of *Rhizobium* and phosphorus fertilizer is effective in P2I1 (P fertilization with a dose of 1 gr SP36*/polybag* and *Rhizobium* with a dose of 2.5 gr *Rhizobium/polybag*).

The average forage production of peanut plants inoculated with *Rhizobium bacteria* and different phosphorus fertilizers is presented in Table 2.

Fresh Matter Production

Table 2 shows that the application of different levels of phosphorus fertilizer has a significant effect ($P<0.05$) on the production of fresh matter forage peanuts. The production of fresh ingredients of peanut forage showed no difference with *Rhizobium inoculation treatment*. However, the production of fresh matter forage peanuts shows differences in the application of phosphorus fertilizers. There is no interaction between *Rhizobium bacteria* and phosphorus fertilizers. The combination of *Rhizobium* and phosphorus fertilizer effectively increases the production of fresh matter in P2I1 treatment (P fertilization with a dose of 1 gr SP36*/polybag* and *Rhizobium* with a dose of 2.5 gr *Rhizobium/polybag*).

Rhizobium the combined phosphorus fertilizer plays a role in increasing plant photosynthesis through the acquisition of nitrogen and phosphorus. This increase is due to the increased efficiency of nutrient use by plants through adaptation mechanisms. *Rhizobium* plays an important role in providing N nutrients, which form root nodules of legume plants that function to fix N in the air into N available to plants. Nitrogen is the main nutrient for plant growth in the formation of plant vegetative organs such as leaves, stems and roots.

Table 1: Average plant height (cm) of peanuts treated with *Rhizobium* and phosphorus fertilizer

Inoculation Bacteria	Phosphorus Level (P)			Average
	P0	P1	P2	
I0	40.33±4.50	46.33±3.51	54.66±19.5	47.11±11.9
I1	41.66±2.08	50.66±4.93	50.33±4.16	47.55±5.57
Average	41.00±3.22	48.50±4.50	52.50±12.83	

P0=0g SP36/polybag; P1=0.25g SP36/polybag; P2=1g SP36/polybag; I0=0g *Rhizobium*/polybag; I1=2.5g *Rhizobium*/polybag.

Table 2: Forage Production of Peanut Plants Treated with *Rhizobium* and Phosphorus Fertilizer (gr/*polybag*)

Treatment	Parameters						
	Fresh Ingredient Production	Dry Matter Production	Root Nodule	Number of Pods	Pod Weight	Seed Weight	Number of Seeds
Inoculation							
I0	43.26±7.32	8.33±1.37	43.00±11.5^{a}	14.00±5.52	22.74±9.87	12.69±4.40	20.22±8.06
I1	46.44±7.59	9.30±1.61	72.55±16.8^{b}	12.67±7.14	19.67±11.12	10.30±4.77	15.33±7.83
Fertilization							
P0	39.05±6.32^{b}	8.08±1.56	53.66±10.0	9.83±5.08	18.22±11.78	7.68±3.02^{c}	13.50±7.31^{c}
P1	44.37±7.30^{ab}	8.57±1.85	55.66±26.7	13.00±5.40	19.31±10.94	11.01±2.59^{b}	14.83±5.31^{b}
P2	51.12±2.46^{a}	9.80±0.50	64.00±23.7	17.17±6.68	19.31±10.94	15.80±4.10^{a}	25.00±6.84^{a}

Different superscripts in a column under specific treatment show significant difference (P<0.05).

Dry Matter Production

Table 2 shows that the application of phosphorus fertilizers with different levels with addition *Rhizobium* does not have a noticeable effect (P>0.05) on the production of dry matter Peanut straw. Phosphorus fertilizers with bacteria *Rhizobium* No effect on peanut production but with the application of phosphorus and bacterial fertilizers *Rhizobium* Can increase metabolism in the plant body, then organic matter is formed higher. This is in opinion (Zainuddin et al., 2020). which states that although adding phosphorus to dry weight production plants does not have a significant effect but the metabolism of peanut plants still increases. The combination of *Rhizobium* and phosphorus fertilizers is effective in P2I1 (P fertilization at a dose of 1g SP36/polybag and *Rhizobium* at a dose of 2.5g *Rhizobium*/polybag).

Effective Number of Nodules

Table 2 shows that applying phosphorus fertilizers with different levels of *Rhizobium* application had a significant effect (P<0.05) on the root nodules. The root nodules showed differences in the inoculation treatment of *Rhizobium bacteria*. However, the root nodules showed no difference in the application of phosphorus fertilizers and the interaction between *Rhizobium bacteria* and phosphorus fertilizers.

The interaction of phosphorus fertilizers with *Rhizobium inoculation* has a marked effect on increasing the root nodules. Optimum combination of P2I1 with fertilizer dose 1g SP36/polybag and *Rhizobium* inoculation at dose 2.5g caused a positive interaction of 20.33. In combination of P0I1 with a dose of fertilizer 0 gr SP36/polybag and *Rhizobium* inoculation at a dose of 2.5g caused a negative interaction of -2.33 (decrease in the number of nodules). The combination of P1I1 with a fertilizer dose of 0.25g and *Rhizobium* inoculation at a dose of 2.5g caused a positive interaction of 18.00 (increase in the root nodules). However, the effect is still lower than the combination of P2I1.

Inoculation *Rhizobium* can increase the root nodules of plants. This is in opinion (Manasikana et al., 2019) which states that the ability of bacteria *Rhizobium* Nitrogen fixation will increase with the age of peanut plants. Bacteria *Rhizobium* It then develops inside the cortical cells, which causes the cells to develop abnormally and eventually form a swelling called a root nodule or "*nodule*". It is in this root nodule *Rhizobium* develops and conducts free nitrogen fixation from air. Effective root nodules are generally large and pink in color because they contain *leghemoglobin* (The heme group attaches to the globin protein in the bacteroid tissue).

Peanut Forage Production

Number of Pods

Table 2 shows that the application of phosphorus fertilizers with different levels of application with the application *Rhizobium* did not have a noticeable effect (P>0.05) on the number of pods of peanut plants. This is because one factor has a stronger influence than other factors so that other factors are covered. Fertilization using phosphorus in legumes can also stimulate the formation of root nodules and the symbiotic work of bacteria *Rhizobium* thus increasing the result of fixation N by *Rhizobium* (Ferdinan et al., 2022). Combination of giving *Rhizobium* and phosphorus fertilizer is effective in P2I0 (P fertilization at a dose of 1g SP36/polybag) and *Rhizobium* at a dose of 0g *Rhizobium* /polybag).

Pod Weight

Table 2 shows that different levels of phosphorus fertilizer and *partial Rhizobium* application did not have a noticeable effect (P>0.05) on peanut plant pod weight. Then together the application of phosphorus fertilizers with different levels and the application of *Rhizobium* have a noticeable effect (P<0.05) on the weight of peanut plant pods. Duncan's test results showed an interaction between *Rhizobium bacteria* and phosphorus fertilizer.

The interaction of phosphorus fertilizers with *Rhizobium* inoculation has a noticeable effect on increasing the weight of pea plant pods. The interaction between *Rhizobium* application (I0 and I1) with fertilizer application (P0 and P1) has a positive effect of 15.18 (also increases pod weight). Furthermore, the interaction between *Rhizobium* application (I0 and I1) with fertilizer application (P0 and P2) also had a positive influence of 6.97 (also increased pod weight). Meanwhile, the interaction of *Rhizobium* application (I0 and I1) with fertilizer application (P1 and P2) has a negative influence of -8.22 (reducing pod weight).

Seed Weight

Table 2 shows that the application of phosphorus fertilizers with different levels has a significant effect (P<0.05) on the seed weight of peanut plants. The results of the Duncan test showed that *the Rhizobium* inoculation treatment showed no real difference (P>0.05), while the application of phosphorus fertilizer showed a real difference (P<0.05). There is no interaction between *Rhizobium* bacteria and phosphorus fertilizers. The seed weight of peanut plants tends to increase along with the increase in the level of phosphorus and *Rhizobium* fertilizers.

Number of Seeds

Table 2 shows that the application of phosphorus fertilizers with different levels of *Rhizobium* application has a significant effect (P<0.05) on the number of seeds of peanut plants. The number of seeds of peanut plants showed no difference in the inoculation treatment of *Rhizobium bacteria*. However, the number of seeds of peanut plants in the application of phosphorus fertilizer that differs markedly (P<0.05) can increase the number of seeds. Then together the application of phosphorus fertilizers with different levels and the application of *Rhizobium* have a noticeable effect (P<0.05) on the number of seeds of peanut plants. There is an interaction between *Rhizobium bacteria* and phosphorus fertilizers.

The interaction of phosphorus fertilizer with *Rhizobium* inoculation has a significant effect on increasing the number of seeds of bean plants. The interaction between *Rhizobium* application (I0 and I1) with fertilizer application (P0 and P1) has a positive effect of 8.67 (also increases the number of seeds). Furthermore, the interaction between *Rhizobium* application (I0 and I1) with fertilizer application (P0 and P2) also has a positive influence of 2.5 (also increasing the number of seeds). Meanwhile, the interaction of *Rhizobium* application (I0 and I1) with fertilizer application (P1 and P2) has a negative effect of -6.17 (reducing the number of seeds).

Quality of Peanut Forage

The average quality of peanut plants inoculated with *Rhizobium bacteria* and different Phosphorus fertilizers is presented in Table 3.

Crude Protein Content

Table 3 shows that the application of phosphorus fertilizers of different levels and application *Rhizobium* partially did not have a noticeable effect (P>0.05) on crude protein levels of peanut plants. Then together the application of phosphorus fertilizers with different levels and application *Rhizobium* exerts a significant effect (P<0.05) on crude protein levels of peanut plants. However, Duncan's test results show interactions between bacteria *Rhizobium* and phosphorus fertilizers do not differ markedly (P>0.05). Increased levels of phosphorus fertilizer tends to increase crude protein levels of peanut plants, especially in conditions *Rhizobium*=0g SP36/polybag and decreased condition *Rhizobium*=2.5g SP36/polybag. Nitrogen and phosphorus are necessary for protein biosynthesis in plant tissues.

Table 3: Forage Quality of Peanut Plants fed with *Rhizobium* and Phosphorus Fertilizers

Treatment	Parameters	
	Crude Protein	Crude Fiber
Inoculation		
I0	13.72±1.58	24.64±1.75
I1	14.29±2.06	23.92±3.30
Fertilization		
P0	13.76±2.36	23.44±2.96
P1	14.25±1.19	24.50±0.92
P2	14.01±1.99	24.89±3.45

P0=0g SP36/polybag; P1=0.25g SP36/polybag; P2=1g SP36/polybag; I0=0g *Rhizobium*/polybag; I1=2.5g *Rhizobium*/polybag.

Crude Fiber Content

Table 3, shows that the application of phosphorus fertilizers with different levels and partial application of *Rhizobium* did not have a noticeable effect (P>0.05) on the crude fiber content of peanut plants. Then together the application of phosphorus fertilizers with different levels and the application of *Rhizobium* have a noticeable effect (P<0.05) on the crude fiber content of peanut plants. However, Duncan's test results showed that the interaction between *Rhizobium* bacteria and phosphorus fertilizer was not significantly different (P>0.05). Along with the increase in the level of phosphorus fertilizer tends to increase crude protein levels of peanut plants, especially in *Rhizobium* conditions=2.5g SP36/polybag and decreases in *Rhizobium* conditions=0 g SP36*/polybag*.

DISCUSSION

Forage Growth of Peanut Plants Inoculated (Table 1), applying phosphorus fertilizer with the right dose can increase the process of photosynthesis which can increase plant growth. This is in accordance with the opinion of Sarumpeat et al. (2019) which states that phosphorus fertilization can be beneficial if the addition is in small amounts. Phosphorus fertilizers can stimulate plant growth and increase photosynthesis ability without consequences that can inhibit the formation of root nodules.

Inoculation *Rhizobium* and phosphorus fertilizers against the growth and production of peanut forage can Increasing the rate of photosynthesis which will eventually produce a large amount of carbohydrates so that the forage weight of peanut plants increases (Table 2). This is in opinion (Taluta et al., 2017) which states that increased forage weight can support the process of plant development, especially on plant leaves. Inoculation *Rhizobium* increases the growth and yield of legume plants. The N element available to plants makes the chlorophyll content in the leaves will increase and the process of photosynthesis also increases, as a result of which plant growth is better so that it affects the fresh weight of plants (Arifiansyah et al., 2020).

Then, application of phosphorus fertilizers with bacterial inoculation *Rhizobium* No effect on crop dry matter production is thought to be caused by soil moisture temperature factors that commonly occur due to high rainfall.

This is in accordance with opinion (Arinanti, 2018) which shows metabolic activity in peanut plants decreases because it is affected by high rainfall. High rainfall results in high soil moisture and unstable temperatures. As a result, the growth of stalks and height of peanut plants will be hampered and will certainly affect the dry weight of the plant.

Phosphorus application in peanut improves root development, promotes other nutrients, water utilization and photosynthetic efficiency, which is necessary for increasing dry matter accumulation and yield production, then nitrogen is key production for legume crops. Amount of nitrogen fertilization is used by the plant, nitrogen absorption and nitrogen fixation by nodules of the root. Development of nodules is affected by different forms of inorganic nitrogen which are responsible for the production of rhizobia. (Halder et al., 2017; Murtaza et al., 2022).

Fig. 2: Root nodules of peanuts.

The process of formation of root nodules occurs, beginning with the excretion of a type of growth factor and food substances including *Tryptophan* by the legume root system. As a result, *Rhizobium* bacteria that happen to be around the roots or that are deliberately inoculated at the time when the plant will be aroused to multiply rapidly. *Rhizobium* bacteria then develop inside the cortical cells, which causes the cells to develop abnormally and eventually form a swelling called a root nodule or "nodule". It is in this root nodule that *Rhizobium* develops and conducts nitrogen fixation free from the air (Fournalika et al., 2021). This root nodule will usually form 15-20 days after planting (Suarez et al., 2020).

The formed root nodules are not all effective for tethering nitrogen from free air. To determine the effectiveness of root nodules, the first visible sign is the color of the inside of the root nodules. Orange or reddish color, effective root nodule size is larger and centered on the main root. A red pigment similar to blood hemoglobin is found in the root nodules between bacteroids and the membrane sheath surrounding them. Such red pigments are called *Leghaemoglobin*. *Leghaemoglobin* in root nodules serve as special electron carriers in nitrogen fixation, regulators of oxygen supply and oxygen carriers (Kharima, 2021).

Addition *Rhizobium* Introduction can increase the number of effective root nodules. Utilization *Rhizobium* As an inolukasi can increase the availability of nitrogen for plants, which can support the increase in productivity of legume plants. Ability *Rhizobium* In tethering nitrogen from the air is influenced by the size of the root nodule and the number of root nodules. The larger the root nodule or the more root nodules formed, the greater the nitrogen tethered (Fitriana et al., 2015).

The flowering phase is one that affects the formation of pods. According to (Islami et al., 2019) suggests that in the flowering phase, N is needed to stimulate the development of ginophores in order to immediately enter the soil and form pods. This is in line with opinion (Vinothini et al., 2018), which states that peanut yields are determined by the quality of flowers in producing ginophores and the ability of ginophores to form pods. On the other hand, the ability of ginophores to form pods is only 15-20%. In addition, fertilizing N, P, and K can increase the number of pods (Damaiyanti et al., 2019), then the result of this study is in agreement with the result of (Turuko et al., 2014; Chimdi et al., 2022) who indicated that all applied P fertilizer rates significantly increased pods per plant over the control and significantly higher number of pods per plant was recorded with P rates of 20 kg ha−1 over rest of the levels.

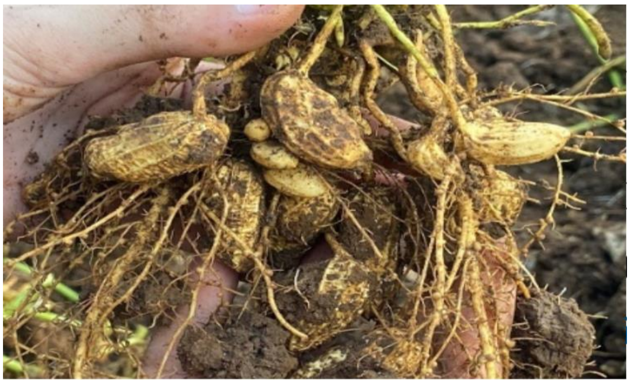

Fig. 3: Peanut pods.

Peanuts begin to bloom approximately at the age of 4-5 weeks. Flowers come out on the armpits of the leaves. The flag of the flower corolla is striped with red at the base. The age of the flower is only one day, blooms in the morning and withers in the afternoon. Peanut flowers are 99.5% self-pollinating and only 0.5% cross-pollinate naturally (Swastika, et al., 2022). Peanut plants produce fruit in the form of pods in the soil that are formed after fertilization. After fertilization, the fruit grows elongated, this is called a ginophore which will later become a pod stalk. Peanut pods are hard-skinned and brownish in color.

Gumelar and Fariyanto, (2020) suggests that seed weight gain in peanut plants occurs when given *Rhizobium* then it will increase the formation and produce effective seeds, then the higher *Rhizobium* for the plant will bear good fruit, as a result of which the increased N element of the fixation process from free air. Utilization *Rhizobium* as inoculants can increase the availability of Nitrogen for plants, which can support increased productivity of legume crops such as seed weight. (Damaiyanti et al., 2019) showed that fertilizing N, P and K can increase the number of pods and the weight of 100 seeds.

The possible reason for an increase in the number of seeds/pods with an increase in the P rate might be P fertilizer for nodule formation, protein synthesis, fruiting, and seed formation, and strain can be made to the availability of growth-limiting primary nutrients such as nitrogen in sufficient amount in the soils, which in turn promotes vegetative growth.

The number of seeds is also influenced by the growing environment and the genetics of the variety itself. As reported by (Munandar et al., 2022) The number of seeds formed per plant varies depending on the variety, soil fertility and planting spacing. P needs in fertilizer are fulfilled because P needs in the formation and filling of peanut seeds are quite available, the greatest P absorption occurs in the formation of pods and seeds. The increase in available P may be due to improved soil conditions that affect the increase in soil microorganism activity, so that the increase in soil microorganism activity will accelerate the availability of P in the soil.

Good plant growth due to the adequacy of N nutrients found in the soil will cause plants to be able to absorb P more effectively. In plants that absorb P, it forms proteins, fats, and various other organic compounds. This is in accordance with opinion (Vomit et al., 2020) that Nitrogen (N) da and Phosphorus (P) are nutrients that are needed by plants in large quantities. Nitrogen is important in the formation of chlorophyll, protoplasm, proteins, and nucleic acids.

Application of phosphorus fertilizer (SP36) to green bean plants causes a tendency to decrease the average of crude fiber. This is likely due to soil fertility factors that play an important role. The decrease in crude fiber content in green bean plants occurs because the addition of phosphorus fertilizer treatment can cause a decrease in crude fiber (Nadila and Sofyan, 2022).

Inoculation of nitrogen fixing bacteria, Rhizobium japonicum, and phosphate solubilizing bacteria, Pseudomonas striata, improved soybean growth, yield, and quality. However, further detailed experimentations under different soil conditions and agro-ecological zones on the capacity of these biofertilizers to fix atmospheric nitrogen and solubilize phosphorus will provide more profound knowledge of their potential in sustainable soybean production (Shome et al., 2022).

Conclusion

Application of phosphorus fertilizers and *Rhizobium inoculation* can increase peanut growth and production root nodules, seed weight, number of seeds and production of fresh matter. However, it does not increase plant height growth, dry matter production, pod count, pod weight and peanut quality. There is an interaction between the application of phosphorus fertilizer and the addition of *Rhizobium bacteria* on the parameters of the root nodules, pod weight, number of seeds, crude protein content and crude fiber. The best treatment combination among several treatments is the combination of P2I1 with a fertilization dose of 1g/polybag with the addition of 2.5g *Rhizobium* inoculation.

Conflict of Interest

All authors declare no conflict of interest

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Author Contributions

NM, Research, analysis of result, original draft preparation, and conceptualization, BN and R, Supervision reset, validation, methodology.

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